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INITIAL STRENGTH DEVELOPMENT OF 'ASTRAPACK' PUMP PACKING MATERIAL

P. Cain
Cape Breton Coal Research Laboratory

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INITIAL STRENGTH DEVELOPMENT OF 'ASTRAPACK' PUMP PACKING MATERIAL

by

P. Cain*

ABSTRACT

Concern by officials of the Cape Breton Development Corporation (CBDC) over the apparently inadequate early strength development of the 'Astrapack' pump packing material on trial in the 9E Coal Road at Lingan Colliery resulted in a request to the CANMET Cape Breton Coal Research Laboratory (CBCRL) to conduct compressive strength tests on the material.

The subsequent testing, carried out in the Soils Mechanics Laboratory at the University College of Cape Breton (UCCB), Sydney, N.S., identified a possible problem in the low water and ambient temperatures in the 9E Coal Road.

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*Research Scientist, Strata Control, Cape Breton Coal Research Laboratory, CRL, CANMET, Energy, Mines and Resources Canada, Sydney.

ESSAI DE RÉSISTANCE INITIAL DES MATÉRIAUX DE REMBLAYAGE "ASTRAPACK"

par

P. Cain*

RÉSUMÉ

Les représentants officiels de la Société de développement du Cap-Breton ont exprimé leur inquiètude à propos des premiers essais de résistance, semble-t-il inadéquats, des matériaux de remblayage "Astrapack" dans la galerie 9E à la houillère Lingan. Ils ont donc demandé au Laboratoire de recherche sur le charbon du Cap-Breton de CANMET, de faire des essais de résistance à la pression sur ces matériaux.

Des essais subséquents, faits au Laboratoire de la mécanique des sols de l'University College of Cap Breton à Sydney (N.-É.), ont identifié un problème probable au niveau des températures basses et ambiantes de l'eau dans la galerie 9E.

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*Chercheur scientifique, Contrôle des strates, Laboratoire de recherche sur le charbon du Cap-Breton, LRC, CANMET, Énergie, Mines et Ressources Canada, Sydney.

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INTRODUCTION

The 'Astrapack' pump packing material developed and manufactured by Pozzament Cement Ltd. of the U.K. is the latest of a new generation of low cement, low solids packing products. The material is delivered as two separate components; the high alumina cement based 'Astracem', and 'Astrabent', a mixture of bentonite and accelerators. During packing each component is mixed to a water:solids ratio of 2.5:1 and pumped into a packing bag in the packhole, where the individual components mix and set. Manufacturer's literature claims a 100 mm cube strength of 0.5 MN/m^2 (72 psi) after one hour, but several instances of total pack collapse after one hour during the early stages of the underground trial of the material in the 9E Coal Road at Lingan Colliery (1) prompted CBDC to request that CBCRL carry out a programme of uniaxial compressive strength testing of standard 'Astrapack' mixes to try to determine the cause of the pack failures. This report gives details of the testing programme, the results obtained and conclusions drawn from them.

TESTING PROCEDURE

The testing procedure used followed ASTM standards as closely as possible with variations as described below.

Sample Moulds

In the initial stages of planning the pump pack monitoring, it was decided that specimens of the cement/bentonite mixture would be collected underground and tested for compressive strength at various time intervals. The standard metal 10 cm cube moulds were too heavy for convenient transport, so CBDC workshop staff made up a set of wooden moulds out of 18 mm marine quality plywood. Each mould was in two pieces and had the precise internal dimensions required. These moulds were used in the laboratory testing programme.

Prior to their initial use, two coats of polyurethane varnish were applied to the inside of each mould. At each casting, a thin layer of oil was lightly brushed over the varnish to assist in separating the moulds and

sample. Due to the very low solids content of the grout after preparation, some difficulty was experienced in retaining the mixture in the moulds. This was solved by packing the mould joints with a heavy grease prior to filling.

After each use, moulds were cleaned thoroughly, oiled, assembled, greased and stored for the next casting.

Sample Preparation

Standard mixes were employed throughout the testing programme i.e. water:solids ratios of 2.5:1 by weight.

To prepare a mix, the required quantitites of 'Astracem' and 'Astrabent' (obtained in 25 kg sacks from the colliery yard) were weighed and the required quantities of water were measured.

The 'Astrabent' slurry was first prepared, mixing for one minute in a bowl using a paint mixing paddle attached to a high speed electric hand drill. Next the 'Astracem' slurry was mixed in the same way. The two slurries were then added together and mixed for another minute using the same mixer and drill. The grout was then immediately cast into the previously prepared moulds.

A total of six batches were cast, 18 specimens in all. The first batch of five specimens leaked and none could be tested. Subsequent castings employed grease packing of the mould joints as described above. The mix ratios of all the batches were 'standard', the difference being the temperature of the water used to make the slurries. Table 1 gives details of the grout temperature at casting. Three samples of Batch 6 were cured at 45°C, beginning one hour after casting until the time of testing.

Batch 4 was wrapped in saran-wrap and foil 24 hours after casting. Batch 5 and the uncured samples of Batch 6 were similarly wrapped one hour after casting. The cured samples of Batch 6 were left in their moulds in the curing oven until just prior to testing.

Table 1 - Grout temperature at casting for the six specimen batches cast

Batch #	Grout Temperature °C	Moulds Cast	Notes
1	10	5	- All moulds leaked, none tested
2	10	5	
3	18	1	
4	20	5	
5	30	5	
6	17.8	8	- Three specimens cured in moulds at 45°C after one hour

Specimen Testing

The specimens were tested on a Soiltest Inc. Versatester 30 M, 150 kN test frame at the University College of Cape Breton Soil Testing Laboratory. The platen advance rate was set to 1.27 mm/min (0.05 inches/min) as recommended in the ASTMS standard for concrete testing.

Prior to use, the load frame was calibrated using proving rings. The calibration was linear and a calibration factor of 1.25 determined in the range 0 - 16 kN. Test results in excess of 15 kN were also adjusted using this calibration factor.

Results

Corrected uniaxial compressive strength for all the samples is summarised in Table 2. Strength development with specimen age is plotted in Figure 1 for Batches 2, 4, 5 and 6.

Table 2 - Summary of test results

Batch #	Age at Testing (hrs)	Compressive Stress at Failure (MPa)	Notes
1	-	-	- moulds leaked
2	1	still slurry	- cast at 10°C up to
	46.5	1.275	3 cm settling in
	47.5	0.845	moulds
3	1	0.081	- cast at 18°C
4	1	0.087	- cast at 20°C dis-
	24	2.281	moulded after 24 hours
	70.3	3.094	and wrapped in saran-
	167	3.344	wrap and foil until
	167	3.375	tested
5	1	0.350	- cast at 30°C dis-
	24.75	2.094	moulded after one hour
	73	2.462	and wrapped in saran-
	168	2.875	wrap and foil until
	168	3.094	tested
6*	1 (uncured)	≈0	- cast at 17.8°C cured
	2 (uncured)	0.325	in moulds at 45°C
	2 (cured)	0.556	uncured specimens dis-
	24 (uncured)	3.437	moulded and wrapped in
	24 (cured)	3.500	saran-wrap and foil
	74.5 (uncured)	4.125	until tested
	74.5 (cured)	3.844	
	168 (uncured)	4.375	

* See text for details of curing procedure.

DISCUSSION

The test results appear to be widely spread and inconclusive. If the varying test conditions are taken into consideration, however, some valuable information can be gained.

The initial test Batches (1 and 2) yield results indicating that low water temperatures (and in practise perhaps low ambient temperatures) increase the gel-time and reduce the strength development of the material, at least in its early stages. In situ water and ambient (still air) temperatures of around 15°C were measured. Low temperatures have been the cause of slow pack strength development elsewhere. These observations are consistent with experience in the construction industry.

A water temperature of 20°C was used in Batch 3 in which two specimens were tested at one hour old. At this time the exothermic hydration reaction of the cement had increased the sample temperature to 25°C, but the one hour strength was still very much lower than the manufacturer's specified strength.

Batch 4 specimens were initially cast at 20°C, dismoulded and saran/foil wrapped after 24 hours. Once again the one hour strength was low, but the 48 hour strength, interpolated from Figure 1, was considerably higher than that of Batch 2 cast at 10°C.

Batch 5 cast at 30°C, gave a very rapid gel-time (5 minutes) but a lower strength development curve than Batch 4. This may be due to evaporation at the higher casting temperature. At one hour the strength, 0.35 MN/m^2, more closely approached the manufacturer's specification (0.5 MN/m^2).

Samples in Batch 6 were cast at 17.8°C to approximate in situ conditions. The one hour strength was very low (approximately nil). After this, both the cured and uncured samples exhibited similar strength development curves which closely matched the manufacturer's specifications.

A possible reason for the variation in late strength between Batches 4 and 6 might be that Batch 4 was not dismoulded and wrapped until 25 hours after casting. This may have allowed some evaporation of water and thus resulted in incomplete hydration. The influence of contained water in the micro-structure of the hydrating cement crystals is not known, but it is not inconceivable that it acts as an incompressible phase in the matrix. Thus loss of water would make the samples weaker and more brittle. This appears to be borne out by observation of specimens kept after testing, but it has not been investigated. Under in situ conditions it is likely that the packing bag maintains a fairly high water content in the pack. The curing of one set of specimens from Batch 6 at 45°C would be expected to produce higher

strengths. Whilst this was true up to about 36 hours, the fact that the cured specimens were left in the moulds uncovered in the curing oven, probably resulted in large amounts of evaporation.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the results of this study:

1. Water and ambient temperatures of the levels measured in situ can be expected to have a major effect on the strength development of the pump pack, especially in the early stages. Heat or hydration developed in the packs will alleviate this problem to some extent in the later stages.
2. In enclosed laboratory specimens, low early strengths appear to have no effect on later strengths. It may be concluded that the material supplied to CBDC is able to reach the manufacturer's specified strengths, therefore the long-term behaviour of the pack material should not cause undue concern.
3. Sample storage conditions have a great influence on their subsequent strength. Water evaporation appears to reduce the strength of the material, although the exact influence of the contained water on the strength of the specimen is not yet understood.

Based upon these conclusions, the following recommendations are made:

1. Where there is a danger of low ambient or water temperatures underground, e.g. during winter months, the water supply should be heated to at least 23°C (the recommended test temperature given by manufacturer). This will decrease the gel-time and reduce settling of the material in the packing bag. Settling produces a layer of water above the cement in the pack bag which offers no effective support. When cast at 10°C, samples settled to 60% of their volume, which represents 84 cm of settlement in situ.

2. Manufacturers of pump packing materials who supply to CBDC should be asked to quantify temperature effects on the strength development of their materials over the range of temperatures experienced underground in the Sydney Coalfield.
3. Controlled storage methods/conditions should be designed and implemented for future pack materials testing.
4. The influence of water in the porous structure of the pump pack on its strength development should be investigated.

ACKNOWLEDGEMENTS

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1. Cain, P. "Preliminary report on the pump packing trial at Lingan Colliery"; CANMET Division Report ERP/CRL 85-52(TR).

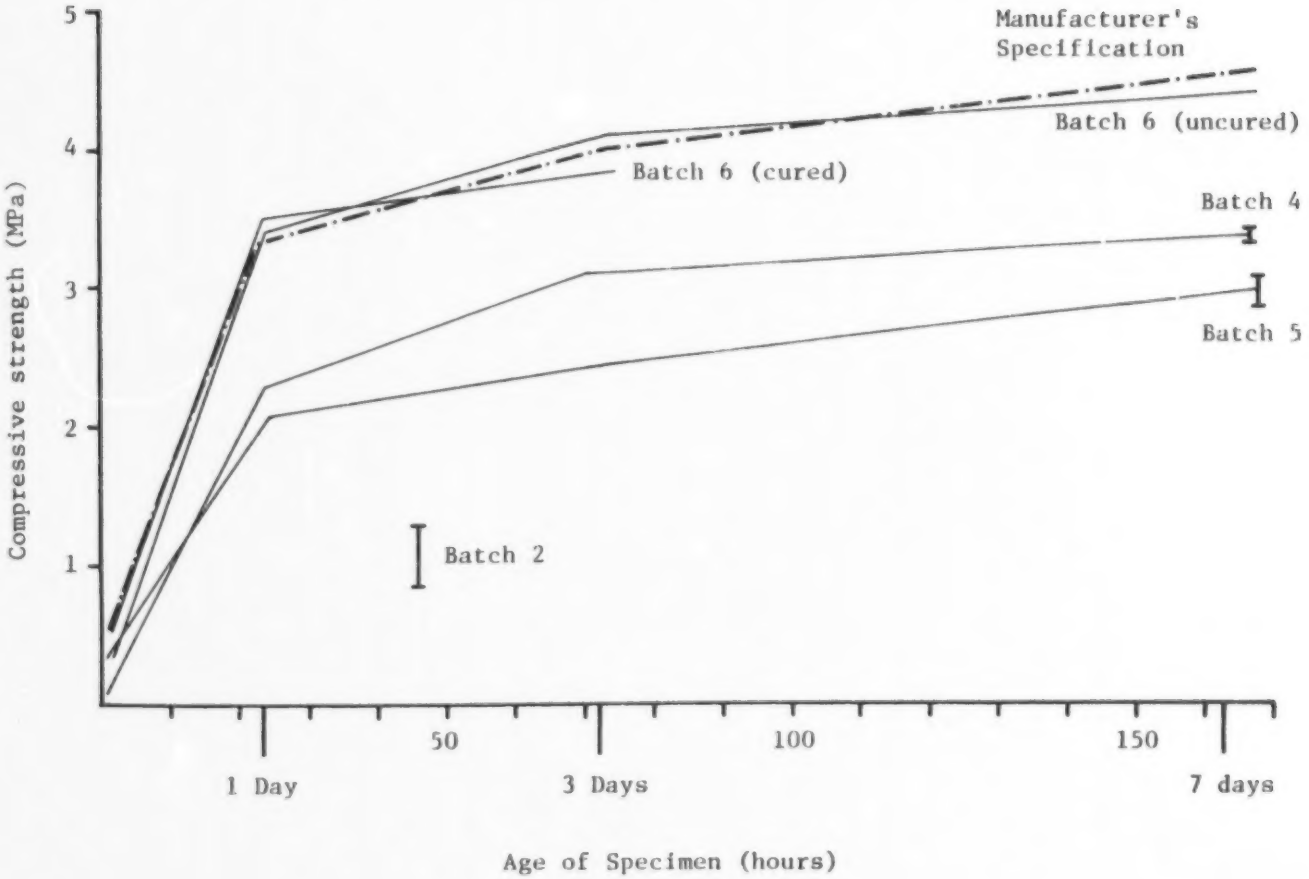

Figure 1 - 'Astrapack' strength development with age